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Oil Sprays for Summer Use

by

Anthony Spuler, F. L. Overley and E. L. Green

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
[2] In cooperation with the United States Department of Agriculture.

TABLE OF CONTENTS

OIL SPRAYS FOR SUMMER USE

Anthony Spuler, F. L. Overley and E. L. Green*

INTRODUCTION

The effectiveness of lubricating oil sprays in the control of insects found on the trees during the dormant period, led investigators to determine the possibility of their use in summer or foliage sprays. It was soon discovered that oils receiving a minimal amount of refinement (sulfonation test 50 per cent) are more or less toxic to plant foliage. Applications of this oil in amounts as small as one-half of one per cent gave appreciable injury to foliage in the experimental orchard at Wenatchee in 1927. In 1926, Gray and deOng (3) found that "toxicity of the oils tested appeared to increase roughly in proportion of the amount of unsaturated compounds present." deOng, Knight and Chamberlain (1) found that severe injury to citrus trees from the use of lubricating oils is associated with the presence of a high percentage of unsaturated hydrocarbons.

The injury from the use of lubricating oil sprays led to the introduction of highly refined and water white oils for summer use. While these oils contained only a small per cent of the unsaturated hydrocarbons and did not show the same toxic effect on foliage as was found with the less refined oils, they nevertheless had an indirect effect which appeared in the form of metabolic disturbances to the tree.

The need for an effective contact spray to aid in the control of such insects as codling moth, red spiders, leaf hoppers and various species of aphids led the Divisions of Entomology, Chemistry and Horticulture of the Washington Experiment Station in 1927 to begin a study of the more highly refined lubricating oils for summer use.[a] This work[b] has now been in progress for four years and it is the

[a] These investigations on oil spray were made in the Wenatchee district with the cooperation of the County Commissioners of Chelan County and the Wenatchee Valley Traffic Association.

[b] Experimental work was carried on as part of the Western Cooperative oil spray project..

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purpose of this publication to set forth some of the more important results of this investigation. These investigations are not complete and this bulletin should be regarded as a progress report.

SPECIFICATIONS FOR SUMMER OILS

Because of the greater susceptibility of plants to oil injury during the growing season, specifications for summer oils must necessarily be different than for oils used in the dormant period. Factors such as refinement and viscosity, of little importance in dormant oils, are of utmost importance in summer oils. On the other hand, the emulsifier and type of emulsion are of utmost importance in oils for dormant use but are generally of little consequence in oils used in summer applications.

Oil Refinement. The process of refining the oil to make it suitable for spray purposes has consisted largely in removing the unsaturated and other chemically active hydrocarbons. A common method for accomplishing this involves agitation of sulfuric acid with oil so that the acid unites with certain constituents of the crude oil. These are then removed with the excess acid. The remaining saturated hydrocarbons are but little affected by this process. The highest degree of refinement of lubricating oils according to present practice requires several expensive treatments, some with fairly strong acid. The degree of refinement is determined by the sulfonation test. This test is conducted by shaking a portion of the oil with a fixed amount of sulfuric acid of a given strength at a given temperature and for a given length of time. The unattacked residue of the sample expressed in per cent is called the "unsulfonatable residue."

Another method of refining the oil was suggested by Edeleanu (2). In this method liquid sulfur dioxide is used, which has a solvent action on the objectionable hydrocarbons. This method is reported to save more of the oil treated than the refining process previously discussed.

Refinement of the oil has not generally reduced the toxicity of the oils to insects. Tests in the insectary on codling moth eggs show that the same rate of killing was obtained with oils of the same viscosity but varying 48 per cent in their sulfonation test.

Highly refined oils are less toxic to plants than those receiving a minimal amount of refining (sulfonation test 50 per cent). In the oils of low refinement injury to foliage is likely to appear in the form of dead leaf tissue. In the highly refined oils injury is largely in the nature of interference with leaf metabolism and cannot generally be recognized as leaf injury.

No differences were noted in the toxicity of oils to plants whether refined by the sulfuric acid or the liquid sulfur dioxide method. This was determined by spraying Jonathan trees with oils differing only in the manner in which they were refined. In these tests two oils, one having a viscosity of 70 seconds Saybolt and the other a viscosity of 50 were used. One half of each lot was refined by the sulfuric acid method and the other by the liquid sulfur dioxide method. No toxic effects to foliage were noted in any of the plots even with three applications of the oil.

Extreme refinement (sulfonation value 98 per cent) does not appear to be necessary since oils ranging in sulfonation value from 85 to 98 per cent have been used with no apparent toxicity to plants.

Viscosity. Viscosity or body is a property of an oil which is measured by the rate of flow in seconds of a certain quantity of the oil through a definite sized opening at a given temperature. The viscosity of oils within even the narrow limits used in these experimental tests (50 to 120 seconds Saybolt) is an important factor in both insect control and in plant injury.

Within certain limits the ovicidal value of the oil increases with an increase in viscosity. Tests in the insectary indicate that the spray strength can be materially reduced if oils of high viscosity are used. The influence of viscosity on the ovicidal value of the oil is shown in Table 1.

Tests in the field where oils of three viscosity ranges were used, show this same trend. In the field tests, trees were sprayed with a combination of oil and lead arsenate in the first three cover sprays. The treatments were the same in every respect except that oils of different viscosity ranges were used. The results are given in Table 2. As pointed out later in this bulletin, oil sprays increase the insecticidal value of the lead arsenate when used in combination with it. The

results in Table 2, therefore, show the effect of viscosity of the oil on the ovicidal and larvicidal value of the combination spray.

Table 1. Influence of Viscosity on Ovicidal Value of Oil. (1928-1930)

Spray strength	Viscosity 50-55 sec.		Viscosity 70-75 sec.		Viscosity 110-120 sec.	
	Total Eggs	Per cent hatched	Total Eggs	Per cent hatched	Total Eggs	Per cent hatched
½ per cent	204	25	469	21	384	10
¾ per cent	761	22	569	15	461	6
1 per cent	500	16	429	11	231	5
1½ per cent	106	15	......	....	157	4

Table 2. Influence of Viscosity on Insecticidal Value of Oil (Field tests, three oil applications 1929-1930)

Test Number	Viscosity 50-55 sec.		Viscosity 70-75 sec.		Viscosity 110-120 sec.	
	Total fruit	Per cent wormy	Total fruit	Per cent wormy	Total fruit	Per cent wormy
1	7745	10.92	....	....	5591	6.06
2	11688	9.12	....	....	13405	4.55
3	5008	23.73	....	....	5038	7.74
4	6119	12.42	....	....	5488	7.10
5	43001	10.90	29744	6.67	....	......

The various tests in Table 2 were made under different conditions and direct comparisons should only be made of the several viscosities in the tests.

Relation to Carbohydrate Synthesis. Although highly refined oils (unsulfonatable residue 85 per cent or higher) have not proved in field tests to be toxic to foliage in the sense that actual leaf tissue was destroyed, they have caused a metabolic disturbance in the leaves which in some cases at least was reflected in tree and fruit growth.

According to Knight, Chamberlain and Samuels (6), "the metabolic disturbances appear to be due to physical rather than chemical handicaps imposed by the intrusion of the oil into the plant tissue." The degree to which this occurs depends largely on the viscosity of the oil and the nature and amount of the oil deposit on the leaves. Trees in the experimental orchard at Wenatchee, Washington, sprayed with several applications of oils ranging in viscosity from 75 to 120 seconds have shown injurious effects under some conditions. This was reflected in a reduction in size of fruit. The trees in these experiments were thoroughly sprayed from all angles, and all parts of the trees were drenched. Efforts were made to wet all sides of the apples in order to control the codling moth. With this type of spraying both sides of the leaves were thoroughly covered with the oil.

In order to determine whether oil sprays, particularly those of high viscosity affected carbohydrate manufacture, studies were made of the starch content of leaves from the sprayed plots. The leaves were collected at intervals of two hours beginning at 4 A.M. and continued throughout the day. The chlorophyll was extracted by boiling the leaves first in water then in 80 per cent alcohol. This was done immediately after the leaves were collected. The chlorophyll free leaves were rinsed in water and then placed in a solution containing one per cent potassium iodide and .3 per cent iodine. This solution colored the starch in the leaves so that the amount could be readily seen by the dark stained areas. The amount of starch present in each leaf was then estimated microscopically by using a series of numbers from 0 to 100, 0 representing those leaves in which no starch was visible, 20, 40, 60, 80 representing increasing amounts of starch, and 100 indicating that the leaf was full. The results of these studies are shown in Figure 1.

It will be noted that the starch content is considerably higher in the oil sprayed leaves and highest in those leaves sprayed with the heavy oil (viscosity 110-120 seconds). It was also found that the transpiration rate of the leaves sprayed with oil was decreased for a considerable time following the application. While the increased starch formation would, at first thought, indicate a stimulation or increased metabolism, this accumulation did not extend beyond the foliage. Knight (5) found that oils of high viscosity choke the vascular system

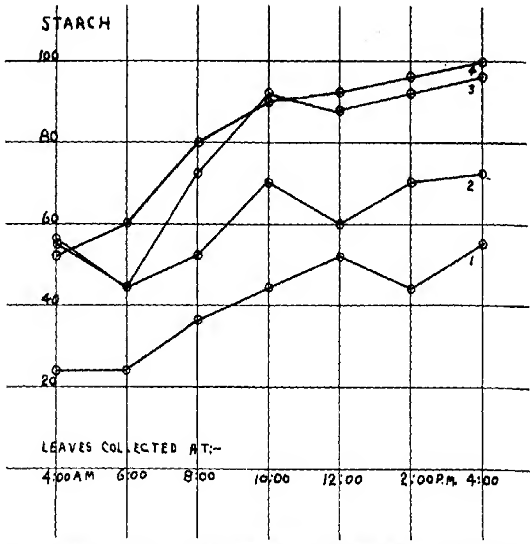


Fig. 1. Starch content of oil and lead arsenate sprayed apple foliage. 1. Lead arsenate spray only. 2. Oil 50-55 viscosity plus lead arsenate. 3. Oil 110-120 viscosity plus lead arsenate. 4. Oil 110-120 viscosity plus lead arsenate.

to a greater or lesser degree, depending upon the amount of oil for an indefinite period. Knight, Chamberlain and Samuels (6) also found that recovery from oil spray applications "is indicated by the accumulation of carbohydrates in the leaves in abnormally large amounts, and that this phenomena is correlated with the fact that the conducting vessels (phloem primarily) are still taxed to capacity with the oil and hence cannot adequately handle the carbohydrates now beginning to be produced in excess of the needs of the leaves."

Volumetric measurements of apples on oil sprayed trees showed that the increased percentage of starch found in the leaves was not reflected in apple growth. In all cases where six applications of either medium (viscosity 70-75) or heavy (viscosity 110-120) oils were used, the fruit on heavily loaded trees was smaller than fruit on lead arsenate sprayed trees carrying similar loads.

Fruit on trees receiving a light oil (viscosity 50-55), however, was even larger than the fruit sprayed with lead arsenate. This can be explained by the fact that red spiders were present on the lead arsenate sprayed trees but were absent on the oil sprayed trees. The interference with leaf metabolism by the light oil apparently did not equal the injury done by the red spiders.

On the other hand red spiders were also absent on the trees sprayed with the medium to heavy oils. Had the foliage on the lead arsenate sprayed trees been free from red spider the difference in the size of fruit on the two oil sprayed plots and the lead arsenate sprayed

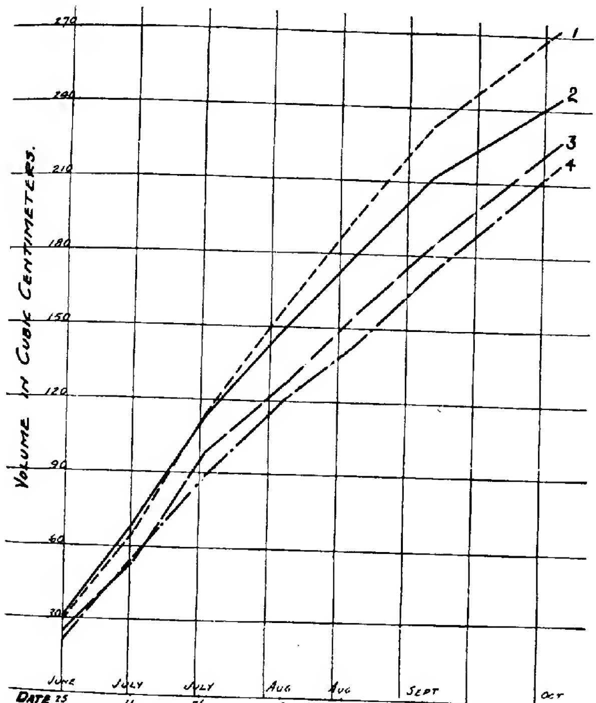


Fig. 2. Effect of oil sprays on growth of Rome Beauty apples, 1929; 1. Oil 50-55 viscosity. 1. Lead arsenate only. 3. Oil 70-75 viscosity. 4. Oil 110-120 viscosity.

plot would have been even greater. In these tests 3259 apple measurements were made and the leaf area limited to 20 normal leaves per apple. The results of these experiments are shown in Figure 2.

Oil Emulsification. Emulsification of the oil is important from the standpoint of even distribution of oil particles in the spray mixture. Oil when added to water rises to the top very quickly and unless violently agitated cannot be held in suspension in the water. The use of various materials, however, such as soap, casein, saponin, calcium caseinate, Bordeaux mixture, dextrins, gum arabic, certain finely ground clays and other colloidal materials with the oil forms, or helps to form, a film around each oil droplet which prevents it from coalescing into a larger body of oil again. The nature of this surrounding film, whether rather tough or easily disrupted is determined largely by the type and quantity of emulsifier used. With the exception of soap, the materials mentioned generally produce a weak film about the oil particles which is easily disrupted.

Emulsions in which this type of interfacial film is formed are known as "quick breaking" since the emulsion breaks immediately upon contact with the tree. This breaking of the film surrounding the oil particle makes it possible for the free oil to come in contact with the tree to which it adheres while the excess water and emulsifier run off. It is possible, therefore, where this type of emulsion is used, to build up a heavy deposit of oil by continued application. The soaps on the other hand form a tough interfacial film about the oil particles and the resultant emulsion is more or less stable. Stability of the emulsion is also largely governed by the relative size of the oil droplets. In the unstable emulsions the size of the oil droplets is relatively large while the oil droplets in the stable emulsions often are very minute and generally exhibit a "Brownian movement." The relative size of oil droplets in the stable emulsion (A) and quick breaking emulsions (B) and (C) are shown in Figure 3.

The oil droplets in the soap emulsion (miscible oil) as shown in (A), Figure 3, were in constant movement and so small that photographing was difficult. In the quick breaking emulsions the oil droplets were so large that but little movement was seen, as is shown by the sharpness of the droplets in B and C.

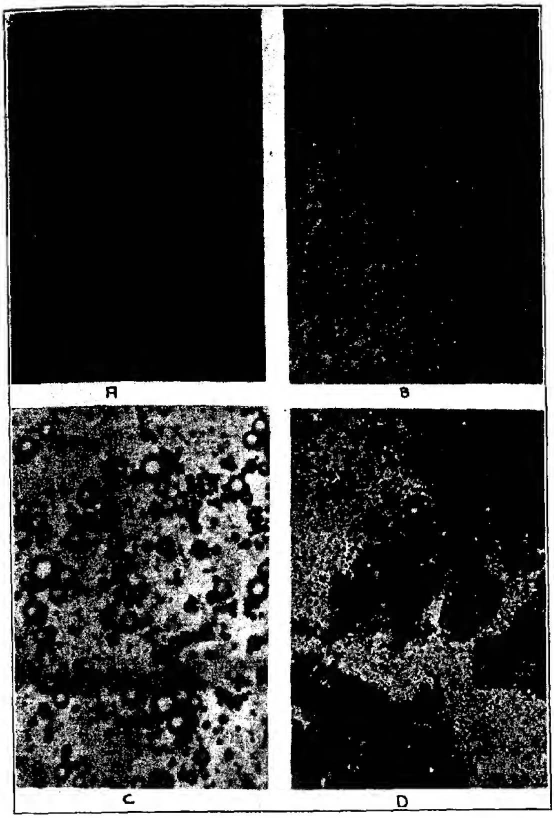


Fig. 3. Photomicrographs showing oil droplets in various emulsions. A, Stable emulsion; B and C, Quick breaking emulsion; D, Flocculation of lead arsenate particles when used with oil emulsions.

The type of emulsion used, whether quick breaking or stable does not seem to be an important factor in either insect control or plant injury. While the quick breaking emulsions deposit more oil and are for that reason more injurious to trees, the differences between the two

types of emulsions are generally not significant commercially because of the small amount of oil used.

Emulsifiers, however, have an important bearing on oil spray combinations in which oil is used with arsenicals or with nicotine compounds. Certain types of emulsifiers and emulsions containing relatively large amounts of the emulsifying agent are assumed in some instances to have caused the formation of soluble arsenic since trees sprayed with these combinations showed arsenical burning of fruit and foliage.

Lead arsenate and flocculation. In 1930 experiments were conducted in the Wenatchee Valley to determine the effect of oil emulsions on lead arsenate. In these tests four oil emulsions and ten brands of lead arsenate were used. The sprays were applied at intervals throughout the season and careful checks were made on all trees to determine the extent of leaf and fruit burning. Two of the oil emulsions used, in which the emulsifier was largely casein and ammonium hydroxide plus a small amount of stabilizing material were instrumental in increasing arsenical burning, particularly with some of the brands of lead arsenate containing a deflocculator. The extent to which arsenical burning was obtained varied from slight burning on approximately five per cent of the leaves to severe burning which resulted in partial defoliation of the trees. Arsenical burning of fruit took the form of small russeted areas, some of which later were attacked by fungi. The arsenical burning of fruit and consequent reduction in grade, varied from zero to approximately 50 per cent.

On the other hand some emulsions cause a flocculation of the lead arsenate particles when used with those brands of lead arsenate that do not contain a deflocculator. It was observed that an emulsion produced by using casein, one ounce, and 27 per cent ammonia water, one ounce, for each gallon of oil emulsified, was not a factor in producing water soluble arsenic when the oil emulsion was combined with any of the lead arsenate products tested. This emulsion on the other hand reduced the amount of arsenical burning of leaves caused by the lead arsenate used alone. The use of this emulsion with all the commercial lead arsenates tested that contained no deflocculator resulted in marked flocculation of the lead arsenate particles. Figure 3 (D).

What is referred to here as flocculation occurs when certain brands of lead arsenate and certain types of oil emulsion are placed together in a combination spray. It appears that the oil droplets of the emulsion as first formed have run together to form rather large globules, and that the lead arsenate has left the water to coat these. Each flake is then a mass of these larger droplets coated with lead arsenate particles. Because of the size of these flakes and their irregular distribution through the water an even distribution of both the oil and the lead arsenate is not to be expected in spraying a mixture in this condition. The actual coverage obtained when these materials were applied is better than was expected, but in several instances where such flocculation has been overcome by the use of spreaders a better control of the codling moth has ensued. The significance of this phenomenon is not definitely known.

Flocculation of this type can be prevented: first, by the use of an oil emulsion which in itself does not produce this phenomenon with lead arsenate; second, by the selection of lead arsenate that contains a deflocculator; and third, by the addition of lime or a spreader containing lime to the oil-lead arsenate combination. Curiously enough the first and second methods named have in most instances brought about arsenical burning. The addition of lime or spreader to the oil-lead arsenate combination has on the other hand served to overcome flocculation as well as arsenical burning in the various combinations tested.

It would seem, therefore, from the work done so far, that a small amount of either lime or spreader containing lime should be added to the oil-lead arsenate spray. This amount should not be greater than is sufficient to prevent flocculation, since the use of relatively large amounts results in a marked decrease in arsenical deposit.

VALUE OF OIL IN INSECT CONTROL

Oils have been regarded as efficient insecticides for a number of years. Probably their greatest value lies in the fact that they lend themselves to effective combinations with other insecticides. They have been effectively used in the control of such insects as aphids, red spiders, leaf-hoppers and have been of great value in the control of the codling moth.

For Codling Moth. The use of summer oils for insect control must be largely centered around the control of the codling moth since the control of those other insects mentioned usually requires the addition of some contact spray to the standard codling moth treatment. For this reason the value of oil sprays must be determined from the standpoint not only of insect control and plant tolerance, but of compatibility with other insecticides used in codling moth control.

As previously pointed out, oil sprays are effective ovicides because they will destroy from 85 to 95 per cent of the codling moth eggs. This, however, is true only when the eggs actually come in contact with the spray. A relatively high percentage of the eggs hatch when laid three or four days after the spray has been applied. The relatively short period of effectiveness of the oil as an ovicide has a direct bearing on its value in codling moth control.

The codling moth is present in the orchard from early May until well into September. During this period eggs may be deposited in varying numbers, depending on temperature conditions and on brood activities. The relative activity of moths in the orchard, as indicated by trap records, is shown in Figure 4.

Because of the more or less continuous activity of the codling moth throughout the season as shown in Figure 4, when oil is used alone, it is necessary to apply it at frequent intervals in order to obtain adequate control. Field tests in which oil was used alone at approximately ten day intervals showed decidedly inferior worm control. As shown later, oil cannot be used at such frequent intervals even if it were effective in insect control, because of injury to plants.

It is obvious, therefore, that if oil is to be used in summer applications and is intended to be a factor in codling moth control it must be combined with other insecticides. This is also largely true where the control of other insects is involved, since applications of oil in addition to those used for codling moth involve too much labor and expense.

Oil-lead arsenate combinations. With this in mind oil spray studies were largely made from the standpoint of spray combinations in which two or more insecticides were involved. Probably the most ef-

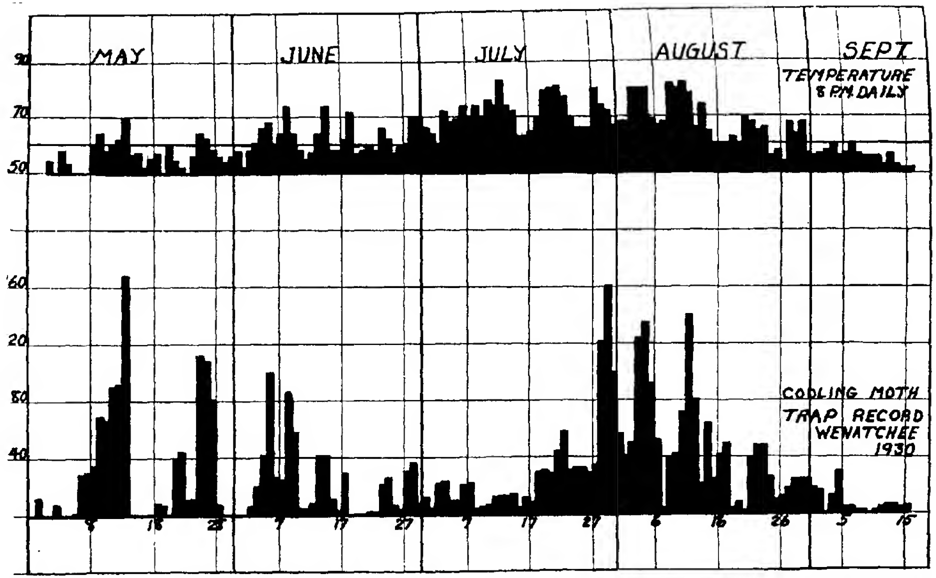


Fig. 4. Codling moths caught in bait traps during season of 1930, and temperature records at 8 P.M. daily for the same period.

fective combination is that of oil and lead arsenate. In this combination the oil retains its ovicidal value and in addition seems to improve the spray coverage of the lead arsenate without bringing about a reduction in arsenical deposit. A report on the value of this combination has been given. (10) Field tests in which this combination was used throughout the season are shown in Table 3.

Table 3. Value of Oil-Lead Arsenate in Codling Moth Control Compared with Lead Arsenate Used Alone.

Exp. No. and year	Treatment	Total Fruit	Sound Fruit	Stings	Worms	Worms per 1000 apples
1 1929	Oil (Vis. 50) ¾% plus lead ars. 2-100 6 covers	35301	33542	1555	557	15.7
	Lead ars. 2-100 6 covers	29658	24767	4667	1499	50.5
2 1929	Oil (Vis. 70-75) ¾% plus lead ars. 2-100 6 covers	9528	9325	258	86	9.0
	Lead ars. 2-100 6 covers	11254	10028	1276	713	63.4
3 1930	Oil (Vis. 70-75) ¾% plus lead ars. 2-100 6 covers					
	Lead Ars. 3-100 6 covers	11651	10659	928	406	34.8

The results shown in Table 3 indicate that a combination of lead arsenate and mineral oil is much more effective than lead arsenate in reducing worm infestation. In these and following tests the oil spray plots were compared with adjacent lead arsenate sprayed plots and interpretations of results should be made on that basis only. This was done because of differences in infestation the year before. That differences exist is shown in a comparison of the two lead arsenate plots.

The columns entitled "worms" and "stings" show the total number of worm injuries without regard to the number of apples on which these blemishes occurred. For example two stings on one apple were counted as two stings etc. The total "worms" and "stings" should therefore, not be construed to mean stung or wormy fruit.

All comparisons were made on a tree basis in which the number of worms per 1000 apples is the index number used. The differences were then computed biometrically and the probable error determined. The comparisons starred in Tables 4, 5, and 6 indicate that the differences in worm entry are not significant.

Although oil used with lead arsenate forms an ideal combination for codling moth control its use throughout the season will cause injury to plants under some conditions and will also complicate the cleaning problem. Because of this limitation in their use, oil sprays should be applied at times when they are the most effective. According to Figure 4, codling moth activity is not uniform throughout the season but fluctuates according to temperatures and other factors. It has been determined that moths deposit eggs in the orchard when temperatures at dusk are 60° F. or above. At such times they are in active flight and are readily caught in bait traps. (9) The number of moths caught in the trap during a given period is, therefore, an index of the relative number of eggs being deposited in the orchard. It will be noted that a majority of the codling moth eggs are laid in a relatively short period of time. Since oils are most effective as ovicides they should materially aid control if applied at a time when most eggs are laid. In order to determine if this would be true under field conditions, a single application of oil was given at the height of the egg-laying period in each of the first and second broods. The results are shown in Table 4.

The results show conclusively that the use of oil in a single application for each of the two broods is very effective in reducing worm injury to the fruit. The results show that the oil-lead arsenate combination spray in the two applications is instrumental in reducing worm entry more than 50 per cent over that of lead arsenate used at the rate of two pounds per 100 gallons in all of the covers. This reduction is not as great when the amount of lead arsenate in the check plots

Table 4. Value of Oil with Lead Arsenate at Height of Egg-Laying Period of First and Second Brood.

Exp. No. and year	Treatment	Total Fruit	Sound Fruit	Stings	Worms	Worms per 1000 apples
1	Oil ¾% (vis. 110-120) plus lead ars. 2-100 1st & 6th cover	35279	32716	2986	585	16.6
1929	Lead ars. 2-100 6 covers	44822	39922	5767	1762	39.3
2	Oil ¾% (vis. 70-75) plus lead ars. 2-100 1st & 6th cover	36199	34350	2072	345	9.5
1929	Lead ars. 2-100 all 6 covers	44555	40992	3868	1072	24.0
3	Oil ¾% (vis. 70-75) plus lead ars. 2-100 1st & 6th covers	15053	14574	441	108	7.1
1930	Lead ars. 3-100 all 6 covers	12832	12044	886	169	13.2
4	Oil ¾% (vis. 70-75) plus lead ars. 2-100 and lime ½-100 1st & 6th covers	8383	7839	546	146	17.4*
1930	Lead ars. 3-100 all 6 covers	8273	7715	590	162	19.8*

* In these tests lead arsenate was used at the rate of 2-100 in 1929 and 3-100 in 1930 in all cover sprays not receiving the oil-lead arsenate combinations.

was increased to three pounds per 100 gallons in 1930. In every case, however, the lead arsenate used in the combination spray was reduced to two pounds per 100 gallons. Hence, the amount of lead arsenate actually applied on the oil spray plots in 1930 was less than that where lead arsenate alone was used.

Oil sprays were also used in three of the first brood cover sprays to determine if such treatments would be effective in controlling the codling moth without at the same time increasing the cleaning problem. The results of these tests are shown in Table 5.

Table 5. Value of Oil-Lead Arsenate Spray in First Brood Cover Sprays.

Exp. No. and year	Treatment	Total Fruit	Sound Fruit	Stings	Worms	Worms per 1000 apples
1	Oil ¾% (vis. 70-75) plus lead ars. 2-100 3 covers	34774	33717	1125	234	6.7
1929	Lead ars. 2-100 all covers	41522	39551	2152	581	13.9
2	Oil ¾% (vis. 50-55) plus lead ars. 2-100 3 covers	43001	41647	1476	363	8.4
1929	Lead ars. 2-100 all covers	53981	51523	2718	683	12.6
3	Oil 1½% (vis. 50-55) plus lead ars. 2-100 3 covers	29781	28672	912	180	6.0
	Oil 1½% (vis. 70-75) plus lead ars. 2-100 3 covers	29390	28280	1151	172	5.8
1929	Lead ars. 2-100 all covers	51460	50241	2576	658	12.7
4	Oil ¾% (vis. 50-55) plus lead ars. 2-100 3 covers	24748	24019	746	107	4.3
1930	Lead ars. 3-100 all covers	12832	11981	886	169	13.1

The oil-lead arsenate combination is more effective than lead arsenate used alone, when used in the first three cover sprays for the first brood of the codling moth, but is not better than a single application of this combination used at the height of the egg-laying period of both broods. It would appear, therefore, that a grouping of three sprays containing oil in the first brood is not using the oil to the best advantage.

Oil used in combination with lead arsenate has complicated the problem of arsenical residue removal. In this combination the lead arsenate deposit is approximately equal to that where lead arsenate alone is used, but greater difficulty is experienced in removing the arsenical residue when oil is used. This is particularly true if the oil is used with lead arsenate in the second brood cover sprays.

Oil-Nicotine combinations. In order to overcome the cleaning problem tests were made with oil and nicotine sulfate as a possible substitute for lead arsenate. As stated before, oil used alone was relatively ineffective in codling moth control and this was found to be true of nicotine sulfate also. The combination of the two, however, has proved to be effective. (10) The results of applying the nicotine sulfate-oil combination in various cover sprays throughout the season are shown in Table 6. In this table each oil-nicotine plot is compared with an adjacent plot receiving lead arsenate only throughout the season.

It will be noted from Table 6 that the nicotine-oil combination is equal to lead arsenate in preventing worm entry, whether substituted for lead arsenate in two applications or used throughout the season. This combination in the second brood cover sprays is even more effective than lead arsenate used at the rate of two pounds per 100 gallons. The outstanding value of the nicotine sulfate-oil combination seems to be its effectiveness in preventing stings. Melander (8) pointed out that the relative efficiency of arsenical sprays should be computed on the basis of a ratio of worms to stings. He stated that the greater the number of stings per worm entry the better the treatment. This does not hold true for either the oil-lead arsenate or the nicotine-sulfate oil combination. In analyzing the data in Tables 4, 5 and 6 it will be noted that the ratio of worms to stings varies with the

Table 6. Value of Nicotine Sulfate-Oil Combination Spray in Codling Moth Control

Exp. No. and year	Treatment	Total Fruit	Sound Fruit	Stings	Worms	Worms per 1000 apples	Total worm Injury per 1000 apples
1 1929	Oil ¾% nicotine-sulfate 1-1600 6 covers	37539	35985	1034	1032	27.5*	55.0
	Lead ars. 2-100 6 covers	45232	41720	3922	1228	27.1*	113.8
2 1929	Oil ¾% nicotine-sulfate 1-1600. 1st & 2nd covers; Lead ars. 2-100 in all other covers	36106	33611	2770	812	22.5*	99.2
	Lead ars. 2-100 6 covers	44555	40992	3878	1082	24.3*	111.1
3 1929	Oil ¾% nicotine-sulfate 1-1600 1st & 6th covers; Lead ars. 2-100 in all other covers	32521	30404	2219	701	21.5	89.8
	Lead ars. 2-100, 6 covers	43744	39201	5352	1460	33.4	155.7
4 1929	Oil ¾% nicotine-sulfate 1-1600. 5th and 6th covers; Lead ars. 2-100 in all other covers	44284	41816	2242	810	18.3	68.9
	Lead ars. 2-100 6 covers	40036	36291	3311	1748	44.6	127.3
5 1930	Oil ¾% nicotine-sulfate 1-1600. 1st & 6th covers; Lead ars. 3-100 in all other covers	7498	7187	315	99	13.2*	55.2
	Lead ars. 3-100 6 covers	12832	12044	886	169	13.1*	82.2
6 1930	Oil ¾% nicotine-sulfate 1-1600 5th & 6th covers Lead ars. 3-100 in all other covers	21833	21033	786	362	16.6	52.6
	Lead ars. 3-100 6 covers	10236	9492	813	246	24.0	103.5
7 1930	Oil ¾% nicotine-sulfate 1-1200 5th & 6th covers; Lead ars. 3-100 in all other covers	16206	15429	718	264	16.3	60.6
	Lead ars. 3-100 6 covers	19754	18494	1393	372	18.8	89.3
8 1930	Oil ¾% nicotine-sulfate 1-1200. 1st & 6th covers; Lead ars. 3-100 in all other covers	11459	10949	510	170	14.8	59.3
	Lead ars. 3-100 6 covers	8273	7715	590	162	10.5	90.9

number of applications of the combination sprays used. For instance, in the oil-lead arsenate combination the ratio is 2.5 to one where six covers of oil were used and five to one where only two or three applications were made. In the oil-nicotine sulfate combination the ratio of worms to stings is one to one where this spray was used throughout the season; 3.4 to one when used in first two covers; three to one when used in the first and last cover and two to one when used in the last two cover sprays only. In lead arsenate (2-100) this ratio is three to one and with lead arsenate (3-100) it is 4.2 to one.

As previously stated above, the nicotine sulfate combination spray is as effective in preventing worm entries as lead arsenate. The additional value it has in preventing stings is, therefore, of great importance when this spray is used in codling moth control.

The oil-lead arsenate combination has been more effective than either lead arsenate used alone or the oil-nicotine combination in preventing worm entry. It is not, however, as effective in preventing stings as the oil-nicotine sulfate combination. Oil used with lead arsenate makes the cleaning more difficult and when used with nicotine sulfate constitutes a rather expensive spray.

The data in the preceding tables show that oil combinations can be used to best advantage in particular cover sprays in the spray schedule. An oil-lead arsenate spray during the height of the egg-laying period of the first brood has proved to be of great value. This spray is effective in reducing the number of worms attacking the fruit by killing the eggs. It also modifies the type of spray coverage on the apple and at the same time maintains a relatively high arsenical deposit. The modification of the spray coverage is shown in Figure 5.

Insectary experiments in which newly-hatched codling moth larvae were placed on the sprayed apples show that lead arsenate is much more effective if combined with oil and that approximately 30 per cent of worms entered the fruit through this spray as compared to 40 and 45 per cent where lead arsenate alone was used. The use of oil with lead arsenate in one of the early cover sprays is helpful in placing a good heavy cover of lead arsenate on the fruit early in the season. This has a direct bearing on worm control during the remain-

der of the season. Oils used in the second brood cover sprays have been generally more effective than early applications, but their use in the late cover sprays with lead arsenate has complicated the cleaning problem.

Spray Schedules. It seems, therefore, that in order to make the best use of oil in a codling moth spray program, the oil should be used at a time and in a combination that will produce maximum results. In order to determine this, experiments were conducted with various spray schedules. In this program the chief object was to develop a spray schedule that would be more effective in codling moth control than the lead arsenate treatment; that would control other insects such as red spiders, aphids, leaf-hoppers, etc.; that would be reasonable in cost; and that would not increase the cleaning problem over that with lead arsenate used alone. Four schedules were developed as shown in Table 7. The plot designated as A-3 is the standard lead arsenate used at three pounds per 100 gallons in every cover spray throughout the season. The sprays were timed by means of the codling moth bait trap. In referring to Figure 4, it will be noted that moth activity, as shown by presence of moths in the trap, began in early May, and that a first peak appeared between the 6th and 13th of May. Allowing approximately 10 days for the eggs to hatch, the larvae of the first general deposit of eggs would begin entering the fruit about the 17th of May. The spray was accordingly applied at that time. Two other peaks follow, with cold weather between peaks. On the same basis of calculation the second and third cover sprays fall on June 2 and 17, respectively. Another minor peak in the latter part of the month of June, together with scattered activity between broods, necessitated a fourth cover on July 2. The second brood activity reaches a first peak on the 29th of July. Because eggs hatch within a few days, the spray was applied at that time and a second in another peak on the 12th of August. Oil sprays are most effective if applied at this time.

Plot C-1 was planned to control the codling moth by the use of an oil spray in the height of the egg-laying period in the first brood and again in the second brood. Because of the residue problem that would be present if lead arsenate were used in all of the cover sprays,

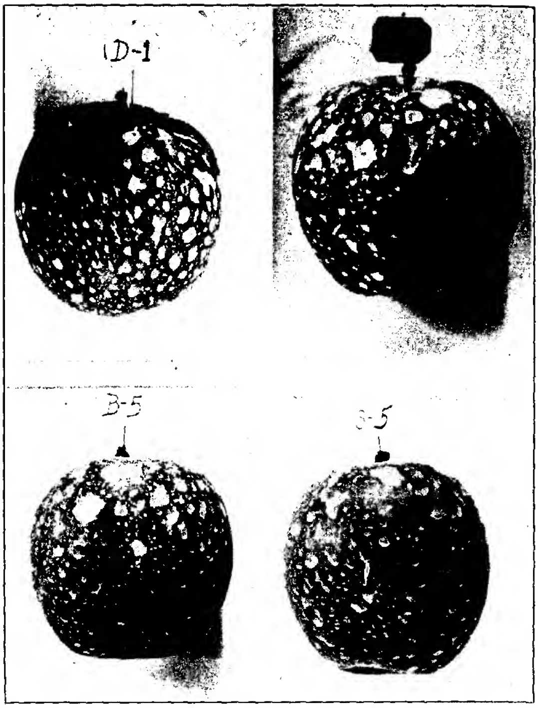


Fig. 5. Spray coverage with oil-lead arsenate and lead arsenate sprays. D-1 and L-1 lead arsenate only. B-5 and S-5 lead arsenate plus oil.

nicotine sulfate was substituted for the lead arsenate in the last two applications. All other sprays consisted of lead arsenate only and were designed to provide a protective coating of poison on the fruit during the first brood activity.

In plot C-2 the mineral oil sprays of plot C-1 were supplemented by adding fish-oil in the next two cover sprays. This spray program placed a heavy arsenical deposit on the fruit during the period of greatest moth activity in the first brood. In addition, the mineral-

Table 7. Spray Schedules Showing the Use of Various Combination Sprays in Two or More Cover Sprays Compared with Lead Arsenate Used Alone Throughout the Season.

Plot No.	Calyx Spray May 3	1st Cover May 17	2nd Cover June 2	3rd Cover June 17	4th Cover July 2	5th Cover July 29	6th Cover August 12
A-3	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100
C-1	Lead ars. 3-100	Oil ¾% Lead ars. 2-100	Lead ars. 3-100	Lead ars. 3-100	Lead ars. 3-100	Oil ¾% Nic. Sulf. 1-1600	Oil ¾% Nic. Sulf. 1-1600
C-2	Lead ars. 3-100	Oil ¾% Lead ars. 2-100	Fish oil ¼% L. ars. 2-100	Fish oil ¼% L. ars. 2-100	Lead ars. 3-100	Oil nicotine sulfate 1-1600	Oil nicotine sulfate 1-1600
C-3	Lead ars. 3-100	Fish oil Lead ars. 2-100	Fish oil ¼% L. ars. 2-100	Fish oil ¼% L. ars. 2-100	Lead ars. 3-100	Oil nicotine sulfate 1-1600	Oil nicotine sulfate 1-1600
C-4	Lead ars. 3-100	Fish oil Lead ars. 2-100	Fish oil ¼% L. ars. 2-100	Fish oil ¼% L. ars. 2-100	Lead ars. 3-100	Oil Lead ars. 2-100	Oil lead ars. 2-100

oils reduced the number of larvae entering the fruit by killing the eggs, and the nicotine sulfate in the second brood prevented a serious arsenical residue problem.

In C-3 the fish-oil was substituted for the mineral-oil in the first cover and was designed to control the codling moth in first brood by a high arsenical deposit. Plot C-4 was added to compare value of oil-lead arsenate and oil-nicotine sulfate in second brood cover sprays.

Fish-oil used at the rate of one quart per 100 gallons with lead arsenate has proved to be very effective in building up arsenical deposits and at the same time in improving the spray coverage. This combination is very effective in preventing worm entry and was used in the spray schedule at a time when a high arsenical deposit should be of great value. It was found that all four of the spray schedules were decidedly more effective in preventing worm injury to fruit than lead arsenate used alone. The value of these sprays in codling moth control is given in Figure 6.

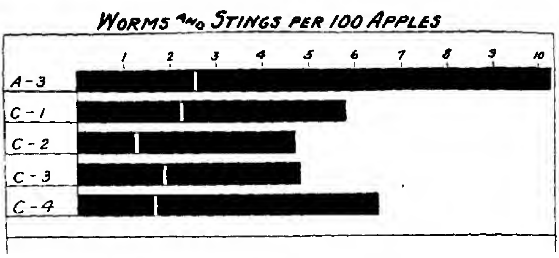


Fig. 6. Value of Special Spray Schedules in Codling Moth Control.

These results show that there is a decided reduction in worm injury where oil was used in some part of the spray program. It will also be noted that those spray treatments containing oil and nicotine sulfate show the greatest reduction in stings. The treatment designated as C12 is probably the most effective since it shows a marked reduction in both worm entries and stings. This treatment also shows the value of fish-oil in the second and third cover sprays for the first

brood. The oil with lead arsenate in the first cover spray was effective in controlling red spiders and no trees in this plot showed red spider infestations although these mites were quite prevalent in other parts of the orchard. Leaf hopper injury common to lead arsenate sprayed trees was almost absent in the C-2 plot. The arsenical residue on the fruit at harvest was but .062 grains AS_2O_3 per pound as compared with .078 grains AS_2O_3 per pound in the lead arsenate plot, (A-3). While the cost was somewhat higher from the standpoint of spray material, the gain in worm free fruit more than offset this extra cost.

For Other Insects. Oil sprays used in the control of the codling moth have an additional value, in that they are an effective spray treatment for such insects as leaf hoppers and aphis and for red spiders.

Leaf hoppers. Several species of leaf hoppers are often found feeding on the foliage of the apple trees. The more important of these are the apple leaf hopper (*Empoasca mali* Le B) and the rose leaf hopper (*Empoa rosae* Linn.) This apple leaf hopper hibernates in both the adult and egg stage while the rose leaf hopper over winters in the egg stage. Early in the spring young nymphs appear and in a short time do considerable damage to the foliage. They feed largely on the undersides of the leaves and their presence can usually be detected by the appearance of small light colored areas on the leaves. Oil sprays are very effective in controlling this insect if applied before the insect develops to the adult stage. Experimental tests, in which oils were applied at intervals throughout the season show that leaf hopper injury was present on those plots not receiving an early application of oil (first cover spray). There are two or more generations.

Aphis. Several species of aphids are commonly found in the orchard. Some species such as the rosy apple aphid, (*Anuraphis roseus* Baker), the woolly apple aphid (*Eriosoma lanigera* Haus.), the black cherry aphid (*Myzus cerasi* Fab.) etc., often become quite injurious. Aphids live over winter in the egg stage. Early in the spring and at about the time the buds first begin to show green the overwintering eggs hatch. Unless checked by parasites, aphids multiply rapidly and several species of these insects cause the foliage to curl. Aphids are sucking insects and feed entirely on the juices of the plants.

Oil sprays used alone have not generally given good aphid control unless the spray strength of the oil was increased to two per cent or more. They have, however, given excellent control at one per cent strength, if combined with nicotine sulfate. Because of the curling of the leaves where a species of aphis such as the Rosy apple aphid is involved, spray applications should be made early and before the curling occurs. This may mean an oil application in the first cover spray or even in the calyx application.

Red Spiders. Oils should be used in at least one application during the summer if red spiders are present. These mites have been responsible for considerable loss to growers because of leaf injury since heavily infested trees fail to produce large and well colored fruit. Four species, the European red spider (*Paratetranychus pilosus* C. & F.), the Clover or Brown mite (*Bryobia praetiosa* Koch), the two-spotted mite (*Tetranychus bimaculatus* Harvey), and the common red spider (*Tetranychus telarius* Linn.) are most commonly found in the orchards. The first two species named deposit overwintering eggs which hatch early in the spring. These species do not spin webs and are found crawling over the surface of leaves and fruit. The last two named species are web spinners and do not deposit overwintering eggs but hibernate in the soil.

Red spider injury was held to a minimum in all of the experimental plots where oil was used. Spray applications should be made before the mites have seriously injured the leaves since spraying after the damage is done will be of little value. Difficulty in wetting the red spider is also experienced if the oil spray applications are delayed until after the leaves are covered with webbing, where the web spinning species are involved.

It is necessary, however, to apply the oil spray thoroughly and to use approximately 1¼ to 1½ per cent of the oil emulsion (viscosity 70-75) for good red spider control. The spray strength can be reduced to one per cent if an oil of higher viscosity is used (viscosity 85-100). An oil of this kind should not be used in more than one application.

San Jose Scale. Repeated applications of oil in the summer have been instrumental in reducing scale infestation by destroying the young migrating scale. Instances have been noted where a light scale infestation was held in check by summer applications of oil only.

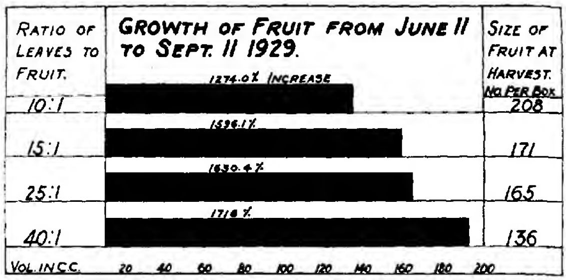
RELATION OF INSECT INJURY TO REDUCTION IN LEAF AREA

Growers are beginning to recognize more and more the value of oil sprays as a control for red spiders, aphids and leaf hoppers. These insects are capable of doing considerable damage to foliage even before they are detected.

Red spiders and leaf hoppers in feeding on the foliage of fruit trees extract the sap and reduce the green coloring matter in the leaves. Continued feeding by these insects will cause the leaves first to turn brown and have a dried appearance and later to drop. The green coloring matter in the leaves (chlorophyll) is necessary in the manufacture of plant food utilized by the tree in its growth and in the production of the fruit crop. Injury to leaves in this manner has the same effect as reducing the leaf area on the tree.

It has been determined that a certain healthy leaf area is required to properly mature fruit. Any reduction of leaf area below this point reduces the size and color of fruit. This was found to be true in the leaf area studies carried on at Wenatchee in 1929 and 1930. Branches of different varieties of apples were selected and sprayed with various oil emulsions. The fruit of two branches on opposite sides of the tree on six trees for each test were measured at regular 15 day intervals. The fruit had been thinned to allow from 10 to 40 leaves per apple and a ring of bark was removed around the branch to prevent a movement of food materials into or out of the branches under test. The methods followed were the same as the methods used by Magness, Overley and Luce.(7) Measurements on the growth of fruit on Jonathan trees from June 11 to September 11, 1929, where the ratio of leaves per fruit was varied 10 to one to 40 to one are shown in Figure 7.

The results such as shown in Figure 7 are the same whether the leaf area is reduced by removing leaves, by burning the leaves with spray materials or by allowing insects to destroy the leaf tissue. It will be noted that a reduction in size of fruit will occur if the leaf area is reduced at any time during the growing season. For this reason growers should avoid using spray materials likely to produce leaf injury. They should also be on a constant look out for leaf feeding insects so as to reduce their work to a minimum.



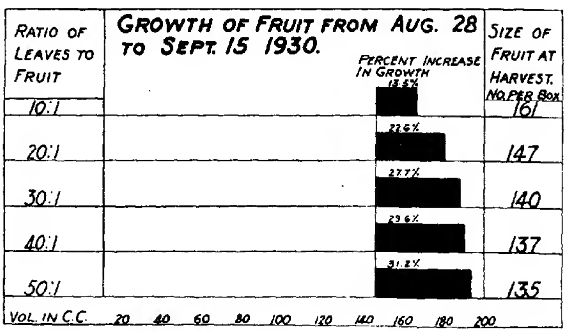


Fig. 7. Effect of leaf area on size of fruit.

The results of various tests show that color of red varieties may be affected in a degree commensurate with leaf injury on heavily loaded trees. Magness, Overley and Luce (7) state, "It is a common observation that very heavily loaded trees may produce fruit of poor color. Since a relatively high sugar content in the fruit is related to best color development, it is apparent that prevention of over-bearing by systematic thinning and production of healthy leaf area are practical ways for the fruit grower to increase the color of the fruit."

In experimental plots where Jonathan trees producing good crops were used the results in the control of red spider and leaf hoppers by oil sprays are shown in reduced injury to foliage. This reduction of foliage injury by insects is reflected in increased color of fruit as shown in Table 8.

Table 8. Effect of Insect Injury to Foliage on Color of Fruit.

Spray treatment	Per cent leaf injury	Average per cent red color
Lead arsenate	30.5	28.9
Lead arsenate	21.3	38.2
Lead Ars. with overhead sprinkler	11.0	54.0
Oil in three applications	1.8	63.5
Nicotine sulfate 6 applications	0	72.3

Factors Influencing Oil Injury. It has been pointed out that oil applied to the leaves in the form of a spray or otherwise will penetrate the leaf tissue. According to Kelley (4) penetration is greater if the oil is applied on the under side of the leaves where the oil gains entrance through the stomatal openings. Oil will interfere with normal process of leaf metabolism and the extent to which this interference causes a retarding or checking of the normal development of fruit and fruit buds depends upon several factors, among which the following are perhaps the most important: (a) the fruit load on the tree at the time of application; (b) the number of sprays applied; (c) the amount of water and plant food available in the soil; (d) temperature at time of application; (e) variety characteristics; and (f) general state of health of trees sprayed.

The use of several applications of oil sprays on Rome Beauty and Jonathan trees in 1929 and 1930 showed a reduction in size of fruit only when the trees were loaded with fruit to a point where the number of leaves per fruit did not exceed 20 for Jonathan and 30 for Rome Beauty. Six applications of oils having a viscosity range of 75 to 120 on Rome Beauty trees carrying a heavy load of fruit caused a re-

duction in the number of fruit buds formed and resulted in a very light bloom and crop the following year. The results of experimental work (7) previously reported show that unless a sufficient leaf area is available to develop fruit and at the same time build up an appreciable concentration of synthesized materials in the buds, fruit bud formation will not occur.

In tests with a varying number of applications of oils of the light to heavy viscosity, the size of fruit in Rome Beauty apples studied showed a reduction only when oils (viscosity 75-120) were used in four or more spray applications.

Trees suffering from a lack of moisture or plant food in the soil show poor leaf development, which in turn is reflected in small and poorly colored fruit. Trees in this condition show further injury and an even greater reduction in size of fruit and color if sprayed with oil.

Leaf and fruit burning may result if oil sprays are applied to trees during periods of high temperature. The degree of injury varies with the temperature and humidity immediately following the spray application and was found to be rather pronounced on such portions of the tree exposed to the direct rays of the sun, when temperatures in the shade rose to 90 degrees F. or higher. Kelley (4) points out "That oils should not be applied when the relative humidity is very high." The type of leaf burning obtained when oil is applied during periods of high temperature is shown in Figure 8.

Varietal Susceptibility. There is a marked difference in varieties of apples as to their susceptibility to injury from oil sprays. In the tests carried on at Wenatchee it was found that the yellow varieties such as the Yellow Newtown are very susceptible to oil injury; a single application of oil (viscosity 70-75) has produced a discolored area on the calyx end. Jonathan and Rome Beauty varieties while not as susceptible as the Yellow Newtown, sometimes show markings on fruit when several applications of medium to heavy oil are given. The Delicious variety on the other hand has shown but little oil injury to fruit.

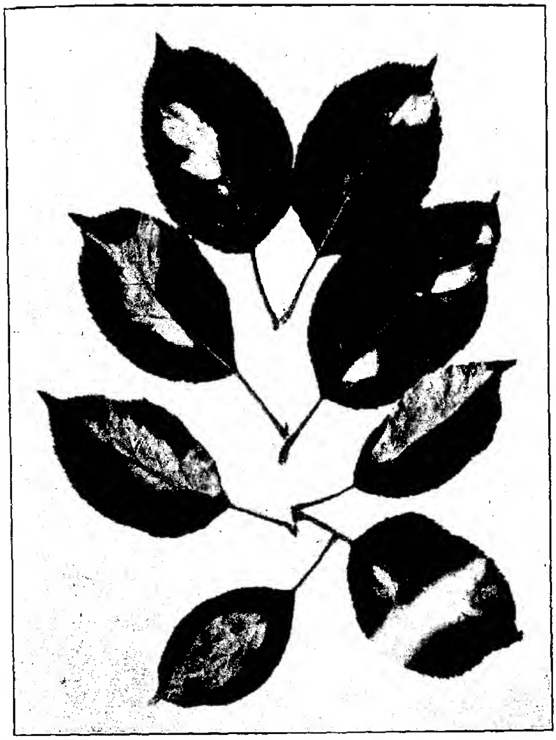


Fig. 8. Foliage from Rome Beauty trees, showing leaf burn after oil sprays followed by high temperatures.

ARSENICAL RESIDUE REMOVAL

The removal of arsenical residue by washing or wiping is more difficult when oils are used in combination with lead arsenate. Cleaning experiments in 1928, 1929 and 1930 have shown that the time of application is an important factor where this combination is used. For instance fruit sprayed with oil and lead arsenate in three cover sprays for the first brood of the codling moth was cleaned with but little difficulty to below the .01 tolerance if cleaned immediately after picking. This was particularly true if one per cent of the hydrochloric acid was used and the solution heated to 100 degrees F.

When, however, the oil-lead arsenate spray was applied after July 15, considerable difficulty in cleaning was experienced. Two applications of this combination spray in the second brood cover sprays made it necessary to use a heated solution of high acid concentration and in some instances salt and kerosene emulsion were added to the solution before the fruit was cleaned to or below .01 grains AS_2O_3 per pound. Where the oil-lead arsenate spray was used throughout the season in 1930, the arsenical deposit at harvest time in 10 analyses averaged .10 grains per pound. This was removed only with greatest difficulty.

Oil should, therefore, not be used with lead arsenate after July 15. If it is desirable to use oil after this date it can be used very effectively with nicotine sulfate. Tests with oil and lead arsenate show that increasing the amount of lead arsenate in this combination beyond two pounds per 100 gallons has not increased control sufficiently to warrant its use. More than that amount serves mainly to increase the difficulty of cleaning the fruit.

SUMMARY

1. Oils of low refinement (sulfonation value 50 per cent) are not suitable for summer use since they are more or less toxic to plant foliage.

2. Highly refined oils are not toxic to foliage in the sense that leaf tissue is destroyed but they do under certain conditions interfere with leaf metabolism.

3. The method of refinement whether by sulfuric acid or by liquid sulfur dioxide is not important from the standpoint of plant injury.

4. Within certain limits the insecticidal value of an oil increases with viscosity. The injurious effect of oil on plants also increases with the viscosity of the oil.

5. The accumulation of starch was greater in oil sprayed leaves than in leaves sprayed with lead arsenate and was greatest in leaves sprayed with the heavy oils (viscosity 110-120). This accumulation was perhaps due to a clogging of conducting vessels by the oil particularly in the case of the heavy oil.

6. Trees with heavy loads of fruit sprayed with six applications of medium (viscosity 70-75) to heavy (viscosity 110-120) oils showed a reduction in size of fruit. Comparisons of fruit in plots sprayed by various oil emulsions were made by first limiting the leaf area on all fruit measured to 20 leaves per apple.

7. Three applications of a light oil (viscosity 50-55) aided tree growth by controlling red spider. Fruit on trees receiving these sprays was larger than on trees sprayed with lead arsenate.

8. The type of emulsion, whether quick breaking or more or less stable, is relatively unimportant in summer oil from the standpoint of either insect control or plant injury.

9. The type of emulsion has an important bearing on spray combinations in which oil is used with lead arsenate.

10. Oils emulsified by the use of casein and ammonium hydroxide cause a pronounced flocculation of the lead arsenate particles when combined with brands of lead arsenate containing no deflocculator. This emulsion did not increase the water soluble arsenic in any of the lead arsenates analyzed.

11. Certain more stable oil emulsions did not cause a flocculation of the lead arsenate particles with any of the brands of lead arsenate used but were instrumental in increasing the water soluble arsenic when used with some brands of lead arsenate that contained a deflocculator. Trees sprayed with the latter combination showed severe arsenical burning of both foliage and fruit.

12. The use of lime or a spreader containing lime with an oil-lead arsenate combination has prevented arsenical burning.

13. Oil sprays are valuable in the control of codling moth, leaf hopper, aphids, red spiders and migrating San José Scale.

14. Oil sprays are not effective in codling moth control when used alone and should be combined with either lead arsenate or nicotine sulfate.

15. The oil-lead arsenate combination is a very effective spray treatment for codling moth control in that the oil will kill from 80 to 95 per cent of the codling moth eggs and at the same time improves the spray coverage of the lead arsenate which renders it more effective.

16. Because of their ovicidal value oil sprays should be applied at the height of the egg-laying period in both broods. Two applications at this time are as effective as three applications in the first brood cover sprays.

17. Oil sprays should not be used in combination with lead arsenate after July 15 since this combination in late applications makes cleaning of the fruit difficult.

18. The combination oil and nicotine sulfate has been as effective in preventing worm entry as lead arsenate (2-100) when used in any or all of the cover sprays. It has been decidedly more effective than lead arsenate in preventing stings.

19. The nicotine sulfate oil combination is most valuable if used in second brood applications. Its use at this time does not increase the cleaning problem since no lead arsenate is used.

20. The use of oil-lead arsenate and fish-oil-lead arsenate sprays in the first brood and nicotine sulfate and oil in the second brood cover sprays forms a very effective spray program for the control of codling moth, red spider, aphids and leaf hoppers.

21. Oil sprays, particularly those of high viscosity, cause metabolic disturbances in the foliage which is reflected in decreased size and color of fruit. The extent to which these disturbances decrease the size and color of fruit is dependent on the load of fruit on the trees, the soil moisture and the variety of fruit.

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